UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE & ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION DECEMBER 2013

TITLE OF PAPER:	**POWER SYSTEM ANALYSIS AND OPERATION**
COURSE CODE:	**EE552**
TIME ALLOWED:	**THREE** HOURS

INSTRUCTIONS:

1. Answer any four **(4)** questions
2. Each question carries 20 marks.
3. Marks for different sections are shown in the right-hand margin.

This paper has 6 pages including this page.

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Question 1

The figure 1 below shows the one-line diagram of a three-bus power system. Bus 1 is the slack bus, bus 2 is a generator bus and bus 3 is a load bus. The line impedances are marked in per-unit in a 100MVA base. Answer the following:

a) Determine the bus admittance matrix of the system. [3]

b) For a load-flow analysis, state what the known and unknown variables are for each bus. [6]

c) If the Newton-Raphson method is to be used to solve the system:
   i. Write the equation for the real power at bus 2, and write also the equations for the real and reactive power at bus 3. [6]
   ii. Write the elements of the following matrices:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = [\,J\,] \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$$

Do not write the full expression of all the elements of the Jacobian matrix. Do, however, write the full expression for the first element of that matrix (J_{11}). [5]

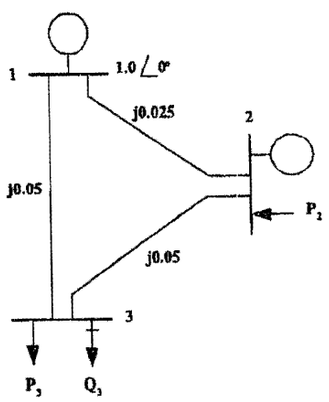

Figure 1: 3-bus power system network

Question 2

a)

i. List three purposes of load flow calculations in a power system. [2]

ii. What makes the load flow problem non-linear? Explain the main steps of the Guass Seidel method. [2]

b) List 4 different types of faults in a 3phase power system. [8]

c) Explain the usefulness of using the Per Unit (PU) system in the analysis of power systems. [2]

d) Why is it so important to optimally allocate power generations to various units in a power system? [5]

e) What is meant by incremental cost in power generation? [1]

Question 3

a) Explain briefly how the method of symmetrical components may be used to represent a 3-phase system of unbalanced voltages. [4]

b) Determine all three symmetrical components of a balanced set of currents with a positive phase sequence. [4]

c) Show that there is no positive or negative sequence current in the neutral connection of a three phase system, that the neutral and zero sequence currents are propotional to each other, and that there cannot be a zero sequence current if there is no neutral connection. [4]

d) Determine the phase voltages corresponding to the following sequencecomponents: [4]

$$\overline{V^0} = 20\angle 80° pu$$
$$\overline{V^1} = 100\angle 0° pu$$
$$\overline{V^2} = 30\angle 180° pu$$

e) For the system shown in figure 3, sketch the zero sequence network. [4]

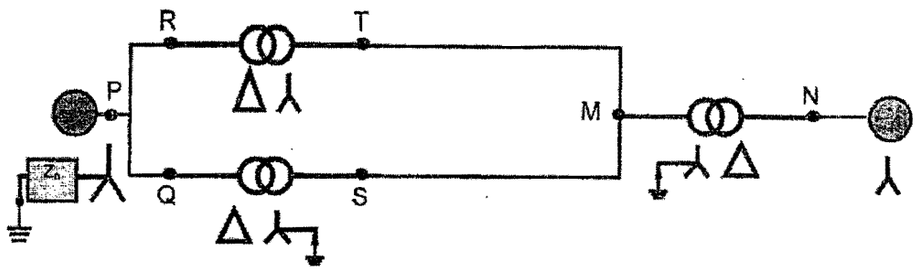

Figure 3: A simple power system

Question 4

Consider the simple three phase power system presented in figure 4.

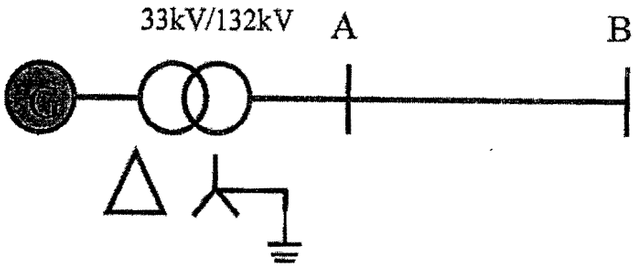

Figure 4: Three phase power system

The system's sequence impedances, for a 100MVA base, are given in Table 4.

	Positive	Negative	Zero
Generator	0.5	0.666	0.8
Transformer	0.3	0.3	0.3
Line	0.115	0.115	0.172

Table 4

a) Sketch positive, negative and zero sequence circuits and place appropriate sequence impedances in these circuits. [3]

b) Show how these circuits should be linked for the evaluation of a single line to ground fault at bus bar B. [4]

c) Determine the fault current. [4]

d) Determine the phase currents through the transmission line A-B. [3]

e) Determine the phase currents through the generator (ignore phase shift across the windings; i.e. assume the phase shift is zero in this case). [3]

f) Determine the fault level at bus B. [3]

Question 5

a) Why do fuel cost characteristics in fossil-fuel units have minimum and maximum limits? [4]

b) A power company has a mixed portfolio of hydro, nuclear, coal and gas based power generation units. Which units in your oppinion would be committed for base load operation and why? [4]

c) A power company has two units that can be engaged on economic dispatch. The operating costs of these units are given by

$$C_1 = 350 + 8.5P_1 + 0.004P_1^2 \quad \$/hr \qquad 300\ MW \leq P_1 \leq 1200\ MW$$
$$C_2 = 400 + 7.5P_2 + 0.008P_2^2 \quad \$/hr \qquad 400\ MW \leq P_2 \leq 1000\ MW$$

Where P_1 and P_2 are in MW.

Determine the power output of each unit and the incremental operating cost(s), if the system is to operate at minimum cost to meet a load demand of 1000MW. Transmission losses are neglected. [12]

Question 6

Draw a per-unit diagram for the system whose one line diagram is shown in figure 6. The three phase and line-line ratings are as follows:

Generator G: 15MVA, 13.8 kV, X = 0.15 p.u.
Motor M1: 5MVA, 13.2 kV, X = 0.15 p.u.
Motor M2: 5MVA, 14.4 kV, X = 0.15 p.u.
Transformer T1: 25MVA, 13.2/161 kV, X = 0.1 p.u.
Transformer T2: 15MVA, 13.8/161 kV, X = 0.1 p.u.

Select a base of 100MVA and 161 kV in the transmission line. [20]

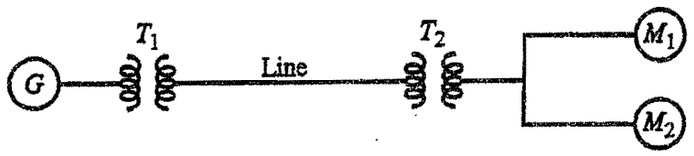

Figure 6